Revisiting the Causaloid Framework

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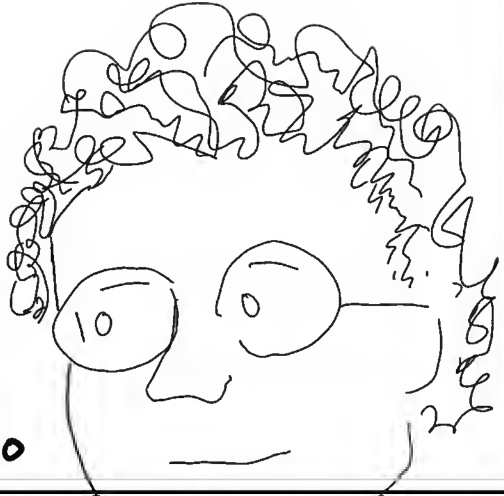
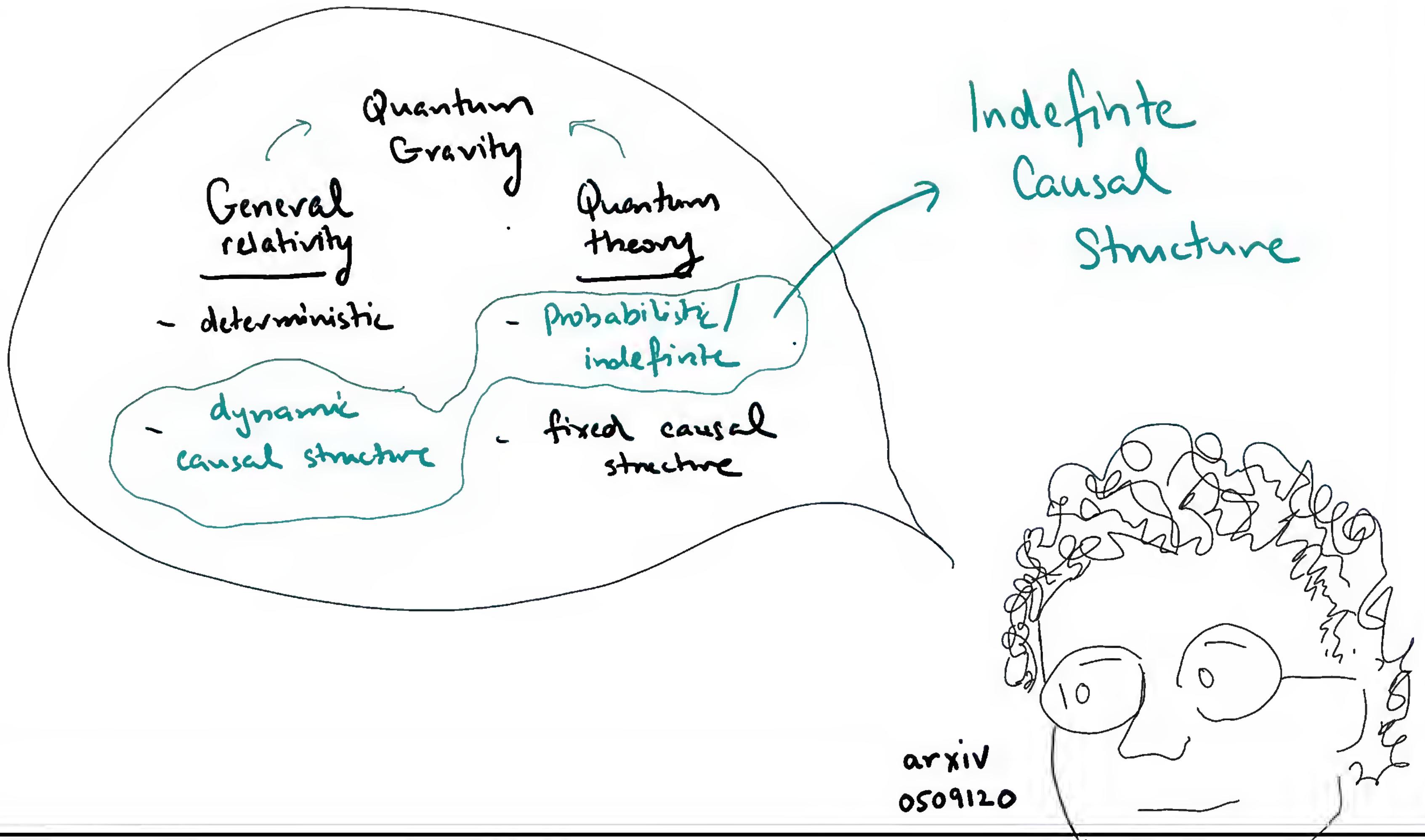
arxiv
0509120





Quantum Gravity
General relativity
- deterministic
- dynamic causal structure
Quantum theory
- probabilistic / indefinite
- fixed causal structure
Indefinite Causal Structure
arxiv 0509120

Operational Methodology

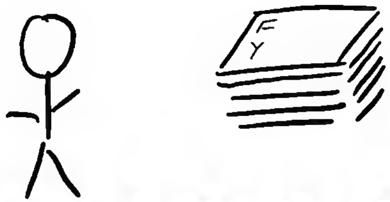
F : Procedure Set

Y : Outcome Set

R_i : Elementary Region

$F_{R_i} := F \cap R_i$: Procedure in R_i

$Y_{R_i} := Y \cap R_i$: Outcome in R_i



"Thinking inside the box"

Operational Methodology

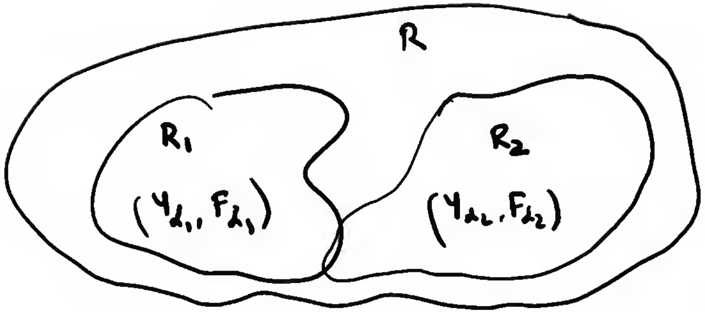
F : Procedure Set

Y : Outcome Set

R_i: Elementary Regions*, $R = \bigcup_i R_i$

$F_{R_i} := F \cap R_i$: Procedure in R_i

$Y_{R_i} := Y \cap R_i$: Outcome in R_i



"Thinking inside the box"

We are interested in the probability

$$P(Y_{\alpha_1} \mid Y_{\alpha_2}, F_{\alpha_1}, F_{\alpha_2})$$

$\forall (Y_{\alpha_i}, F_{\alpha_i})$ in R_i and $\forall R_i \in R$

$\alpha_i = 1, 2, \ldots$

Redundancy & Compression

A physical theory will correlate some of these probabilities to give a smaller set

This is PHYSICAL COMPRESSION

In the causaloid framework, there are three levels of compression

1^{st} level

Consider only a single region R_1

$$P(Y_{\alpha_1} \mid F_{\alpha_1}) \equiv p_{\alpha_1}$$

$$p_{\alpha_1} = r \cdot p$$

where $p = \begin{pmatrix} p_1 \\ \vdots \\ p_{\alpha_1} \\ \vdots \end{pmatrix}$

and $r = (0\,0\,0 \ldots 1 \ldots 0\,0)$

or $r_i = \delta_{i\alpha_1}$

1^{st} level

Consider only a single region R_1

$$P(Y_{\alpha_1} | F_{\alpha_1}) \equiv p_{\alpha_1}$$

$$p_{\alpha_1} = r \cdot p$$

where $p = \begin{pmatrix} p_1 \\ \vdots \\ p_{\alpha_1} \\ \vdots \end{pmatrix}$

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or $r_i = \delta_{i\alpha_1}$

But there are infinite possible measurement/procedure!

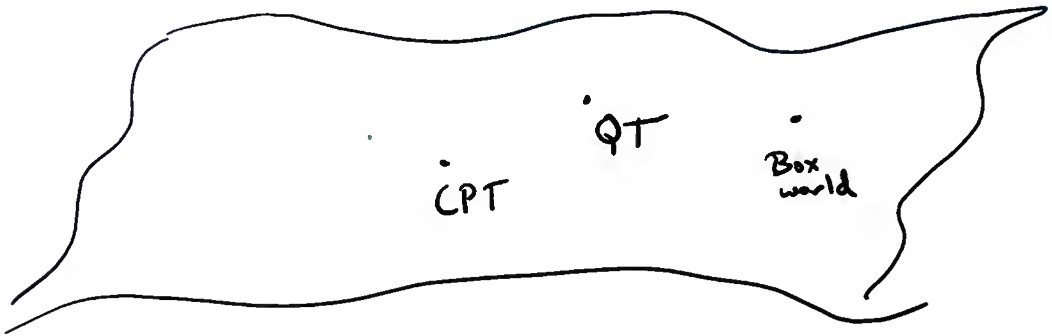
We can choose a fiducial set Ω_1 to fully characterise a state

$$p_{\alpha_1} = \lambda^{l_1}_{\alpha_1} p_{l_1} \quad l_1 \in \Omega_1$$

$$\alpha_1 \longrightarrow l_1 \in \Omega_1$$

1st level

This is nothing but the compression used to define the landscape of Generalised Probability theory used in reconstruction of QT using new axioms.



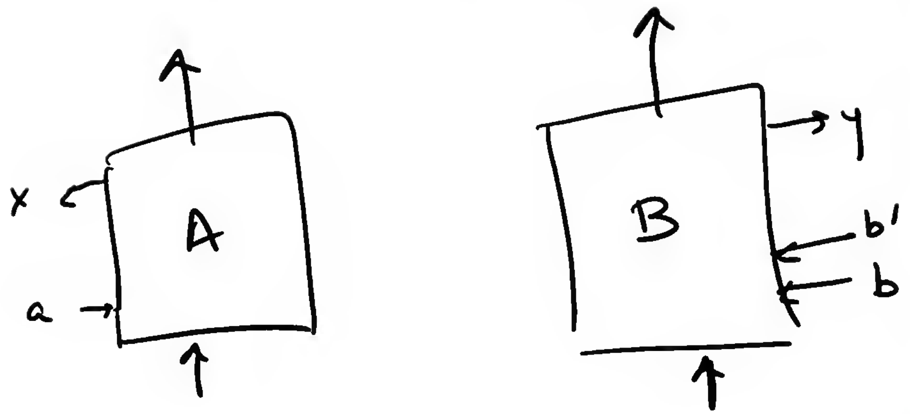
Generalised Prob theories (Non-locality)

	local	$P_{success}$ (non-local game)
CPT	✓	0.75 (local bound)
QT	✗	~0.85 (Tsirelsen's bound)
PR boxes	✗	1,00 (logical bound)

What does the violation of causal inequalities mean?

Causal Inequality
(Oreshkov, Costa, Brukner)

Guess your neighbor's input?



$$P_{success} = \frac{1}{2}\Big(P(x=b \mid b'=1) + P(y=a \mid b'=0)\Big)$$

if $P_{success} > 3/4 \rightarrow$ violation!

Landscape

	$P_{success}$ (GYNI Game)
DCS +QC-CC +QC-QC	0.75
QT + ICS	?
?	1,00 (logical bound)

Can there be a landscape of probabilistic theories with indefinite causal structure?

(Causaloid ?)

2nd level

Consider two (or more) regions R_1, R_2

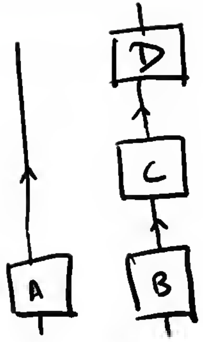
$$P_{\alpha_1,\alpha_2} = \underbrace{\Lambda^{\alpha_1}_{l_1}\,\Lambda^{\alpha_2}_{l_2}}_{1^{st}}\;\underbrace{\Lambda^{l_1 l_2}_{k_1 k_2}}_{2^{nd}} \cdot P_{k_1 k_2}$$

$$l_1 l_2 \ldots \longrightarrow k_1 k_2 \ldots$$

$$k_1 k_2 \in \Omega_{12} \in \Omega_1 \times \Omega_2$$

$$l_1 l_2 \in \Omega_1 \times \Omega_2$$

TYPES



1. $A \times B$
2. CB causally adjacent
3. $[D\,?\,B]$ supermap/comb

Causally adjacent type

show compression

3^{rd} level

Further compress!

$\Lambda^{l_i}_{d_i}$ $\forall R_i$ (1^{st} level)

$\Lambda^{k_i k_j \ldots}_{l_i l_j \ldots}$ $\forall R_i, R_j \ldots$ (2^{nd} level)

$k_i k_j \ldots \in \Omega_{ij \ldots}$

$l_i l_j \ldots \in \Omega_i \times \Omega_j \times \ldots$

Ansatz (if no loops)

$$\Omega_{1 \ldots n} = \mathcal{O}\left(\frac{\prod_{\{ij\}}^{n_2} \Omega_{ij}}{\left(\prod_i^{n} \Omega_i\right)^{x^{n-2}}} \right)$$

reorder

Thoughts?

Thank You!